

“Conservation Practices for Climate Change Adaptation”



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Thank You!
USAID, SANREM, Virginia
Tech, INIAP and
Universidad Estatal de
Bolivar



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The Soil and Water Conservation Society invited the authors to review the science of conservation practices and their potential for climate change mitigation and adaptation.



Conservation practices to mitigate and adapt to climate change

Jorge A. Delgado, Peter M. Groffman, Mark A. Nearing, Tom Goddard, Don Reicosky, Rattan Lal, Newell R. Kitchen, Charles W. Rice, Dan Towery, and Paul Salo

Climate change, in combination with the expanding human population, presents a formidable food security challenge: how will we feed a world population that is expected to grow by an additional 2.4 billion people by 2050? Population growth and the dynamics of climate change will also exacerbate other issues, such as desertification, deforestation, erosion, degradation of water quality, and depletion of water resources, further complicating the challenge of food security. These factors, together with the fact that energy prices may increase in the future,

double those of nonirrigated systems. The yields of nonirrigated systems could also potentially be reduced due to these stresses. Since there is a direct relationship between soil and water conservation practices and maintaining and/or increasing productivity, the research suggests that without the application of the best soil and water conservation practices, it will not be possible to maintain the productivity levels that are needed to feed the additional billions of people the world is expected to have by 2050. A sound scientific approach that applies concepts in agronomy, soil sci-

entific societies provide opportunities for scientists, conservation practitioners, consultants, farmers, and the general public to get together to share ideas and could be great forums for discussing the principles summarized in this document.

This review of current science strongly suggests that the future of the planet's food security will depend on how water and soil resources are managed today and in the future. These challenges can be met by maximizing soil and water conservation to develop sustainable systems essential to mitigate climate change and adapt to it.



CHAPTER TWO

Conservation Practices for Climate Change Adaptation

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Photo NASA

ADVANCES IN
Agronomy

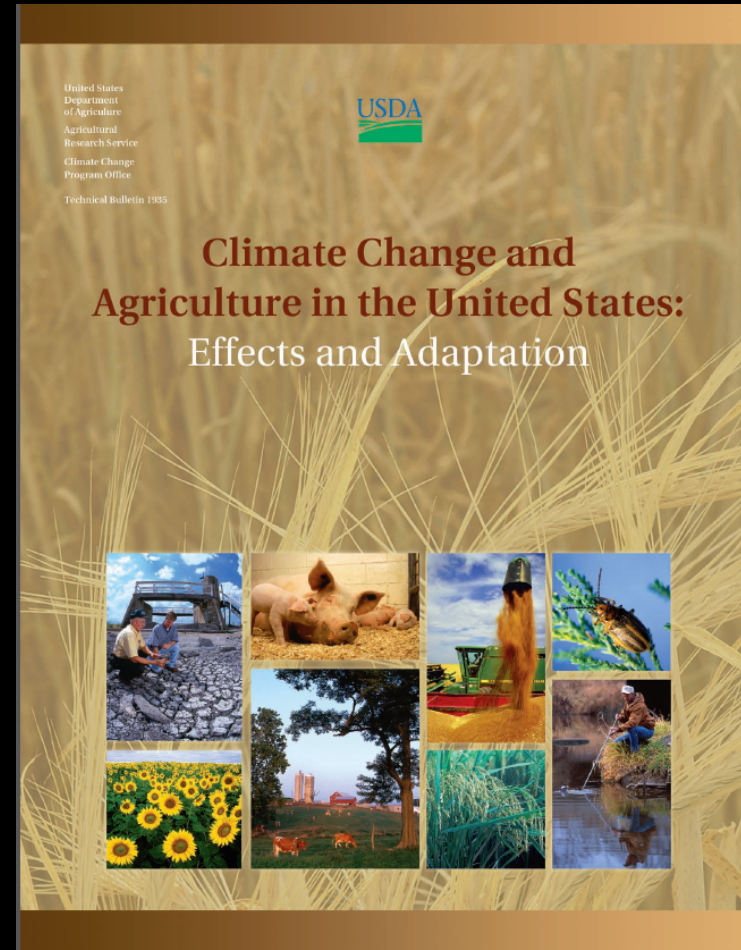
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Walthall, C.L., J. Hatfield, P. Backlund, L. Lengnick, E. Marshall, M. Walsh, S. Adkins, M. Aillery, E.A. Ainsworth, C. Ammann, C.J. Anderson, I. Bartomeus, L.H. Baumgard, F. Booker, B. Bradley, D.M. Blumenthal, J. Bunce, K. Burkey, S.M. Dabney, J.A. **Delgado**, J. Dukes, A. Funk, K. Garrett, M. Glenn, D.A. Grantz, D. Goodrich, S. Hu, R.C. Izaurralde, R.A.C. Jones, S.-H. Kim, A.D.B. Leaky, K. Lewers, T.L. Mader, A. McClung, J. Morgan, D.J. Muth, **M. Nearing**, D.M. Oosterhuis, D. Ort, C. Parmesan, W.T. Pettigrew, W. Polley, R. Rader, **C. Rice**, M. Rivington, E. Rosskopf, W.A. Salas, L.E. Sollenberger, R. Srygley, C. Stockle, E.S. Takle, D. Timlin, J.W. White, R. Winfree, L. Wright-Morton, and L.H. Ziska.



USDA Technical Bulletin 1935. USDA-ARS, Washington, DC.
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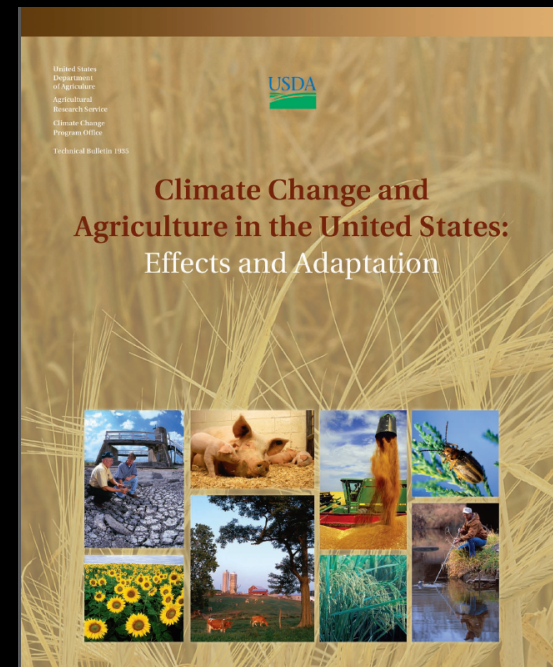


Climate Change and Agriculture in the United States: Effects and Adaptation (USDA Technical Bulletin 1935), a USDA report that serves as a technical reference for the National Climate Assessment (NCA), was published in 2012. The National Climate Assessment (NCA) is a mandated report produced approximately every 4-5 years that provides the U.S. Congress and the President of the United States information on the status of the impact of climate change in the United States. The National Climate Assessment Technical Reference Document covered for the first time the area of soils and conservation practices. This national report stated that by 2050 climate change will impact livestock and agricultural systems and that we need to use conservation practices to enhance the ability of the United States agricultural sector to adapt to climate change.

USDA-ARS Soil Plant Nutrient Research Unit 2013 Report



Photo NASA



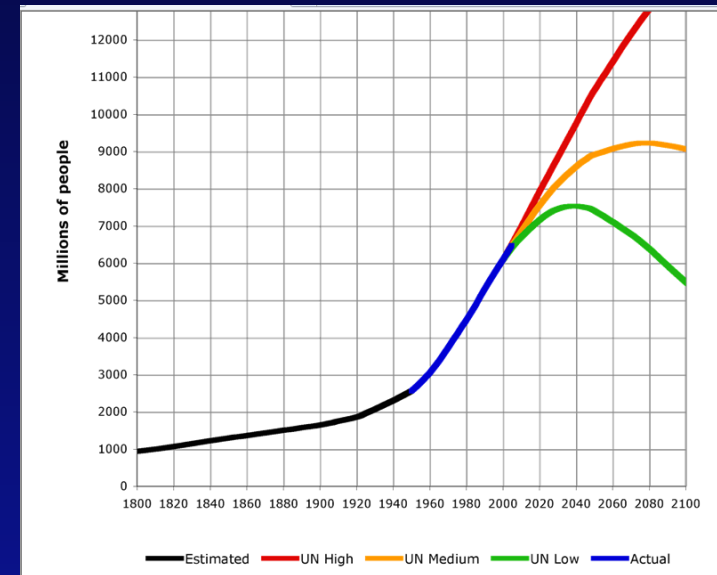
The 20th century's Green Revolution showed that science-based solutions could provide answers to global challenges to the benefit of societies.

Despite the success of the Green Revolution, today there are new concerns, and the threat of climate change is among the most severe threats that face our planet in the 21st century (USDA NRCS 2010).

Major World Challenges Related to Soil and Water Conservation

By 2050, the world population is expected to increase by 2.4 billion people, and as the economies of countries with large populations improve, even more pressure will be put on the world's agricultural systems. This increased demand for resources coupled with climate change could threaten the potential to achieve food security.

<http://upload.wikimedia.org/wikipedia/commons/7/77/World-Population-1800-2100.png>



Major World Challenges Related to Soil and Water Conservation

Population growth and the development of new, stronger economies, such as those of China and India, are increasing the demand for world resources.

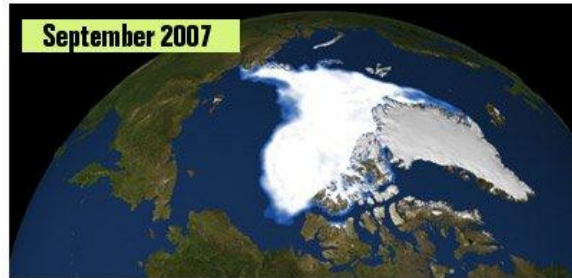
Major World Challenges Related to Soil and Water Conservation

- Climate change is occurring, and the implementation of sound conservation practices will be key for each country's health, social stability, and security.

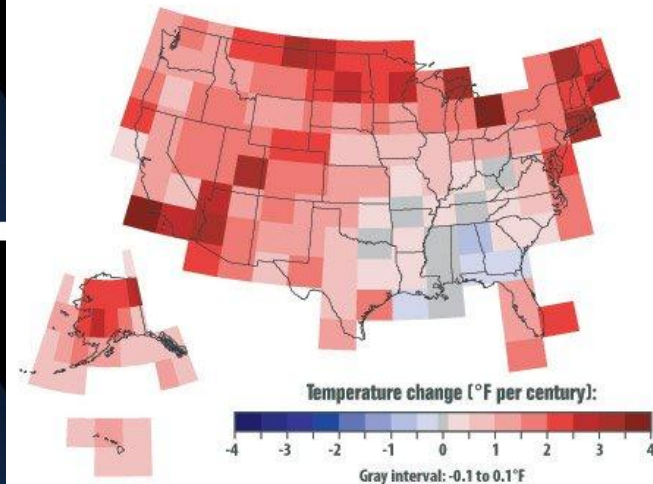
Muir Glacier, Alaska, 1941 and 2004



Arctic Sea Ice



Rate of Temperature Change, 1901–2008



Nonirrigated systems could also see their yields potentially reduced due to these stresses since it has been reported that **for every increase in temperature of 1°C (1.8°F)**, there is a potential reduction in yield (**Grain yield declined by 10%**), not only from heat stress, but also from the interaction of heat stress and drought stress that may be put on crops (Peng et al. 2004; Auffhammer 2011; Lobell et al. 2011).

<http://www.scientificamerican.com/article.cfm?id=climate-change-impacts-staple-crop-yields>

Cereal Killer: Climate Change Stunts Growth of Global Crop Yields

A crop-yield analysis reveals that warming temperatures have already diminished the rate of production growth for major cereal crop harvests during the past three decades

By David Biello | May 5, 2011 | 41

For example, across Africa, an increase in temperature of 1°C under drought conditions could affect 100% of the maize area, potentially reducing yields by at least 20% (Auffhammer 2011; Lobell et al. 2011).

Major World Challenges Related to Soil and Water Conservation

- Extreme weather events are creating environmental problems, accelerating the rate of erosion and threatening agricultural production needed for food security.



Photo EPA



Photo ARS



Photo NRCS

Additionally, climate change can increase the potential for higher erosion rates, which is also of concern because erosion has been reported to lower agricultural productivity by 10% to 20% (Quine and Zhang 2002; Cruse and Herndel 2009).

Source:

Iowa

NRCS



Bakker et al. (2004) conducted a detailed analysis of 24 studies that were published during the 1970s to early 2000s examining erosion's effects on productivity and that measured the quantity of lost productivity per amount of eroded soil.

They found that the average yield lost across the different methodologies was 4.3%, 10.9%, and 29.6% loss in soil productivity per every 10-cm loss of soil measured with comparative plots, transect methods, and desurfacing experiments, respectively.



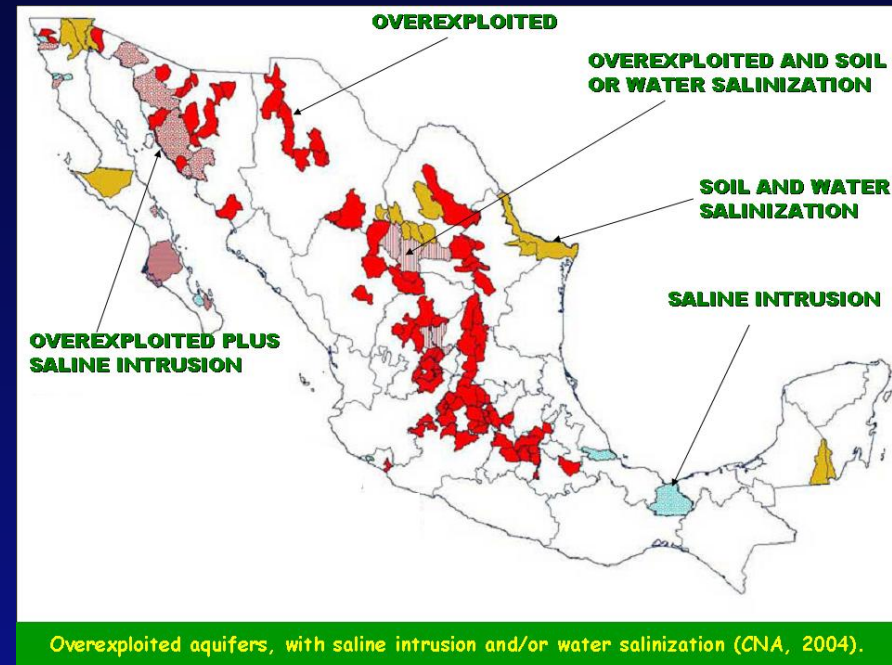
Bakker et al. (2004) concluded that the best methodology to represent the effects of erosion was the plot methodology and that an average of 4% loss in productivity per every 10 cm of soil loss should be considered realistic as far as the negative impacts to yield production from erosion.

More important was the report from Bakker et al. (2004) showing that the relationship of yield losses to soil depth lost will be convex, so any further losses in soil depth after the first 10 cm of soil lost will become increasingly severe and damaging to soil quality, reducing yield by a greater amount.



Major World Challenges Related to Soil and Water Conservation

- Since irrigated systems have, on average, double the yields of non-irrigated systems, the depletion and salinization of these key world resources results in additional pressure to increase agricultural productivity.



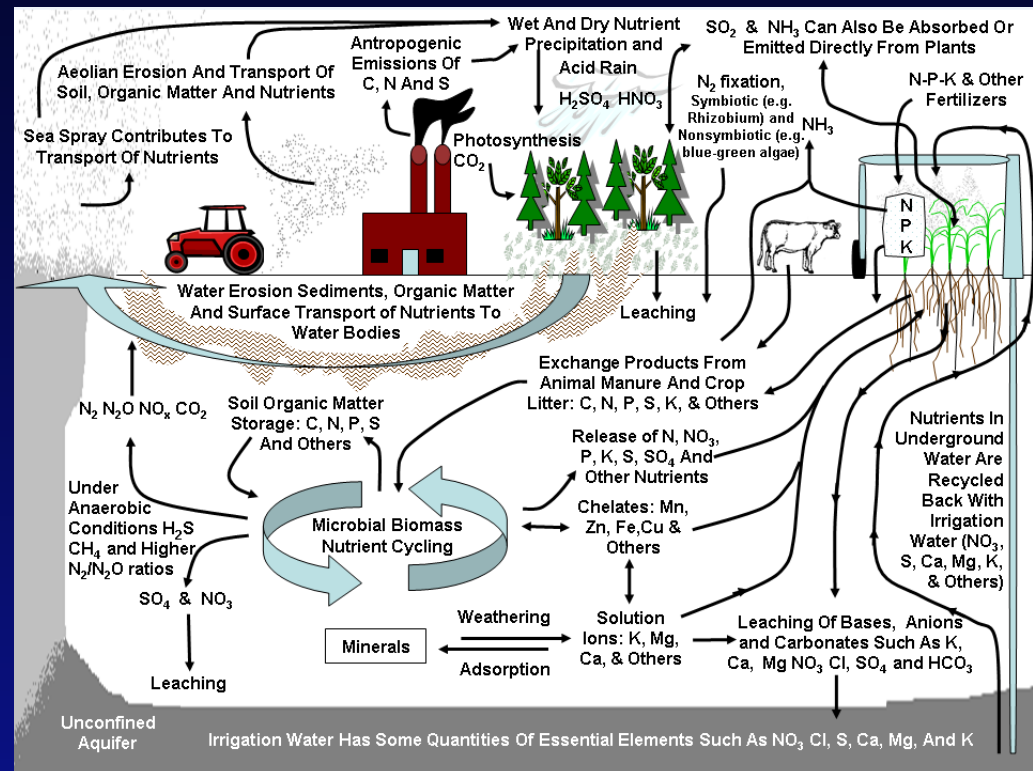
This presents a serious concern because, on average, irrigated systems have yields that are twice those of nonirrigated systems (Rangely 1987; Bucks et al. 1990; Tribe 1994).



The Carbon and Nitrogen Cycles and Agricultural Influences on Greenhouse Gases

Greenhouse Gases Contributed by Agriculture are an Important Factor in Climate Change.

Agriculture plays an important role in the GHG fluxes of CO_2 , N_2O and CH_4 , contributing 6% of total United States GHG emissions (USEPA 2010b).



United States
Department
of Agriculture

Agricultural
Research Service

Climate Change
Program Office



Technical Bulletin 1935

Climate Change and Agriculture in the United States: Effects and Adaptation



USDA

Quotes from the USDA report (USDA 2012 – released 2013):

“Burning of fossil fuels, deforestation, and a variety of agricultural practices and industrial processes are rapidly increasing the atmospheric concentrations of CO₂ and other greenhouse gases (GHGs) (IPCC 2007a, pg. 10).”



USDA

Quotes from the USDA report (USDA 2012 – released 2013):

“Scientific evaluation of the effects of global climate change done as part of the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4), new studies in the peer-reviewed scientific literature (e.g., Allison et al. 2009), and assessments by the U.S. Global Change Research Program, the U.S. National Research Council, and other scientific bodies provide strong evidence of ongoing changes in the Earth climate system.”



Fig. 3.6. Projections of U.S. summer surface temperature from a 16-model ensemble for a low emissions scenario (SRES-B1, top panels) and a high emissions scenario (SRES-A2, bottom panels) relative to 1970-1999. The near-term differences between scenarios (left panels showing the 2040s) are much smaller than the long-term differences (right panels showing the 2080s). Data source: CMIP3.

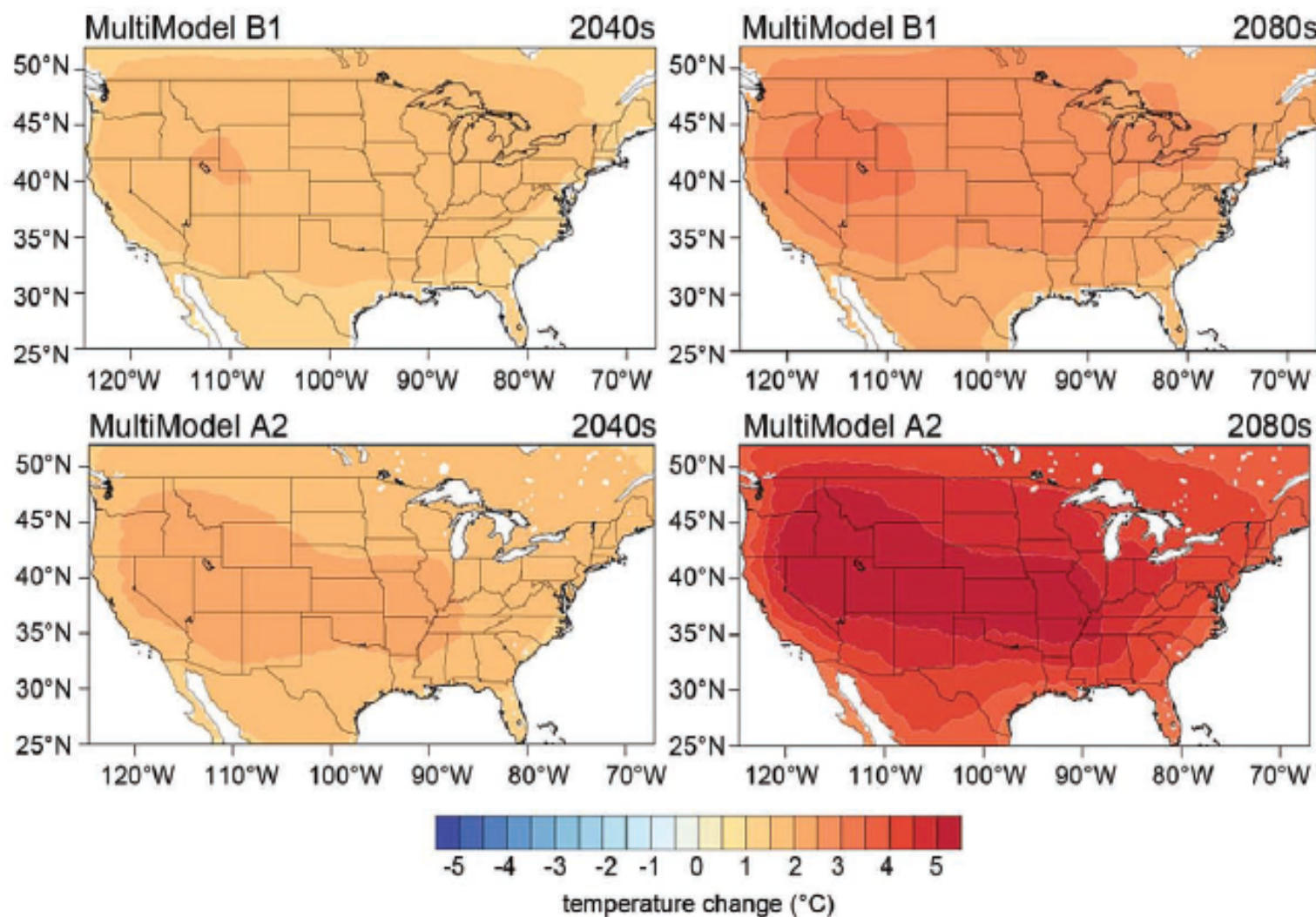


Fig. 3.9. Summer precipitation projections for a low emissions scenario (SRES-B1, upper panels) and a high emissions scenario (SRES-A2, lower panels) relative to 1970-1999. Data source: CMIP-3.

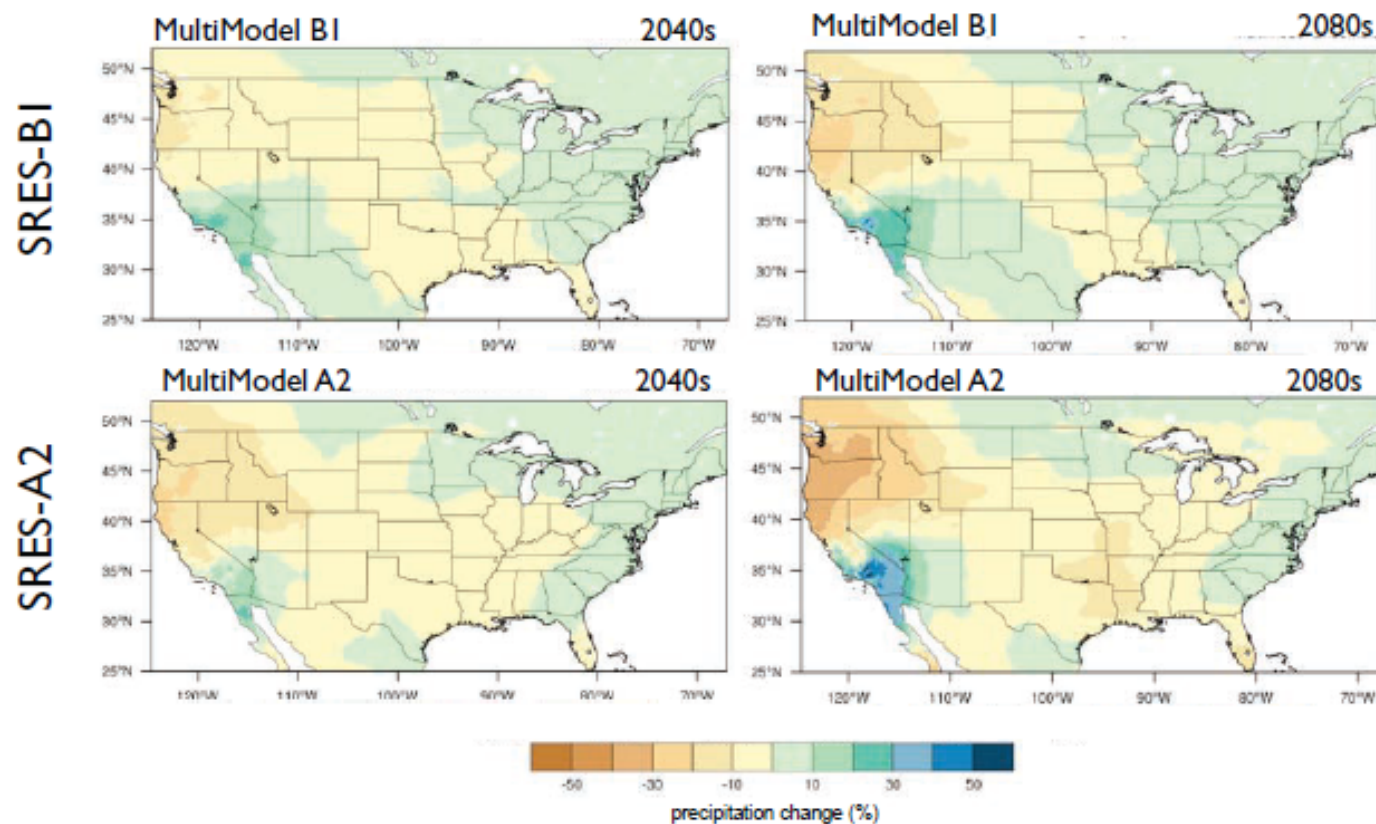
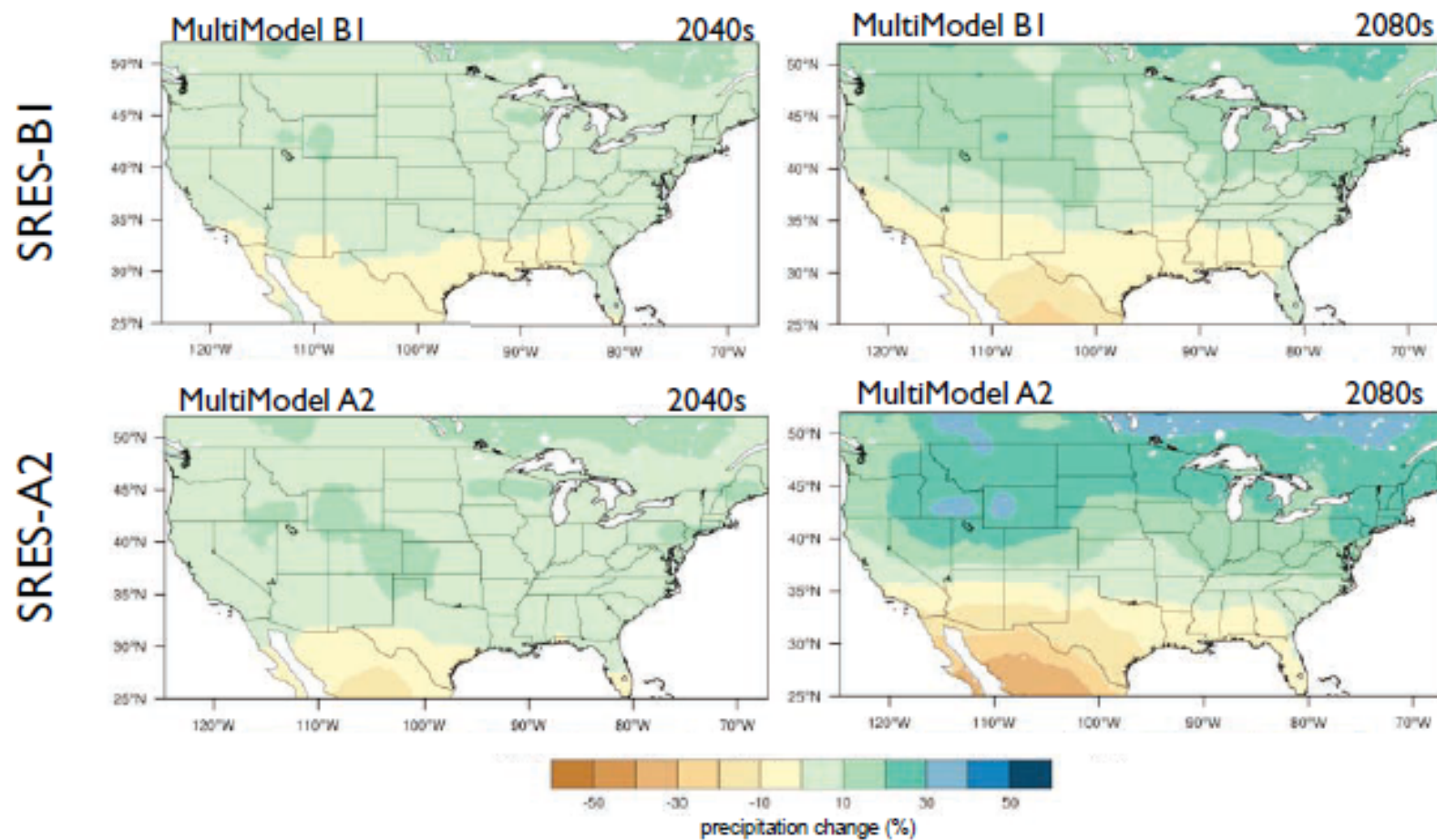


Fig. 3.10. Same as 3.9 but for winter precipitation projections. Data source: CMIP-3.



USDA

Quotes from the USDA report (USDA 2012 – released 2013):

“Increases of atmospheric carbon dioxide (CO₂), rising temperatures, and altered precipitation patterns will affect agricultural productivity. Increases in temperature coupled with more variable precipitation will reduce productivity of crops, and these effects will outweigh the benefits of increasing carbon dioxide. Effects will vary among annual and perennial crops, and regions of the United States; however, all production systems will be affected to some degree by climate change. Agricultural systems depend upon reliable water sources, and the pattern and potential magnitude of precipitation changes is not well understood, thus adding considerable uncertainty to assessment efforts. **(Key Messages pg. 1).”**



USDA

Quotes from the USDA report (USDA 2012 – released 2013):

“The predicted higher incidence of extreme weather events will have an increasing influence on agricultural productivity. Extremes matter because agricultural productivity is driven largely by environmental conditions during critical threshold periods of crop and livestock development. Improved assessment of climate change effects on agricultural productivity requires greater integration of extreme events into crop and economic models. (**Key Messages** pg. 1).”



USDA

Quotes from the USDA report (USDA 2012 – released 2013):

“Projections for crops and livestock production systems reveal that climate change effects over the next 25 years will be mixed. The continued degree of change in the climate by midcentury and beyond is expected to have overall detrimental effects on most crops and livestock. (**Key Messages** pg. 1).”



USDA

Quotes from the USDA report (USDA 2012 – released - 2013):

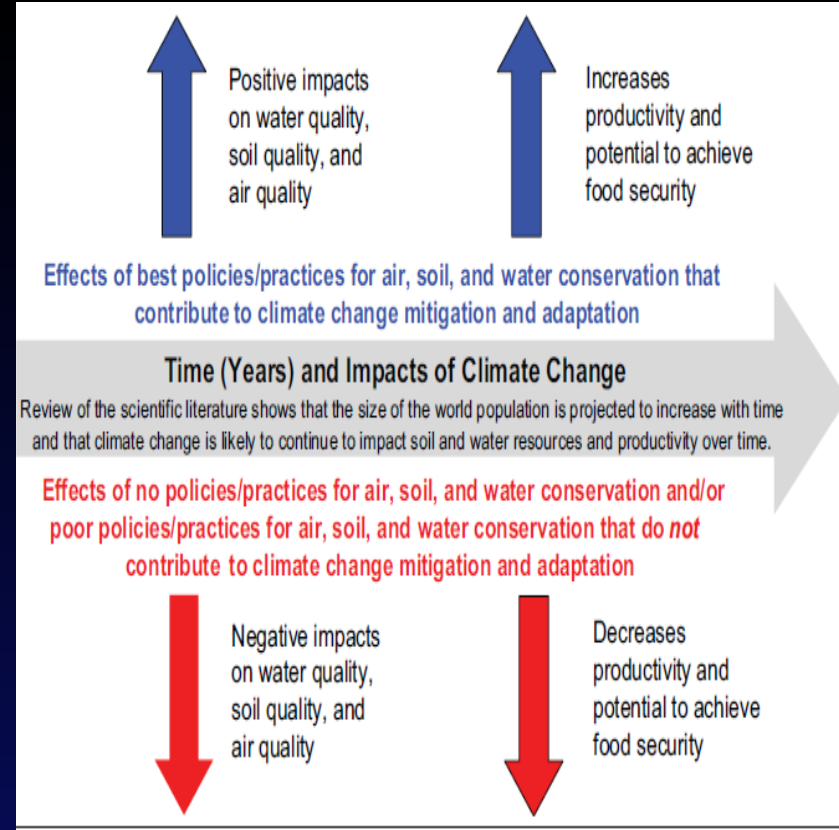
“The vulnerability of agriculture to climatic change is strongly dependent on the responses taken by humans to moderate the effects of climate change”

..... “Anticipated adaptation to climate change in production agriculture includes adjustments to production system inputs, tillage, crop species, crop rotations, and harvest strategies. New research and development in new crop varieties that are more resistant to drought, disease, and heat stress will increase the resilience of agronomic systems to climate change and will enable exploitation of opportunities that may arise. (**Key Messages** pg. 1-2).”



The scientific literature suggests that with use of good policies, conservation programs, and practices we could have a better opportunity to achieve food security (good air, soil and water quality), while with bad policies and/or a lack of policies/conservation practices for climate change mitigation and adaptation, we will have lower air quality, soil quality and water quality, and there will be less potential to achieve food security.

Delgado et al. 2011 *Journal of Soil and Water Conservation*



Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

- Develop Communication that Connects Science to Land Managers.
 - *Better communication with farmers and farmers' groups is key.*



Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

- Develop Communication that Connects Science to the Public.
- *Better communication with the general public is essential to increasing awareness of the benefits of soil and water conservation*



Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Communication of Soil and Water Conservation Programs

- Ongoing Training Essential.
 - Education programs and the mentoring of new personnel are important for maintaining an educated workforce.*



Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

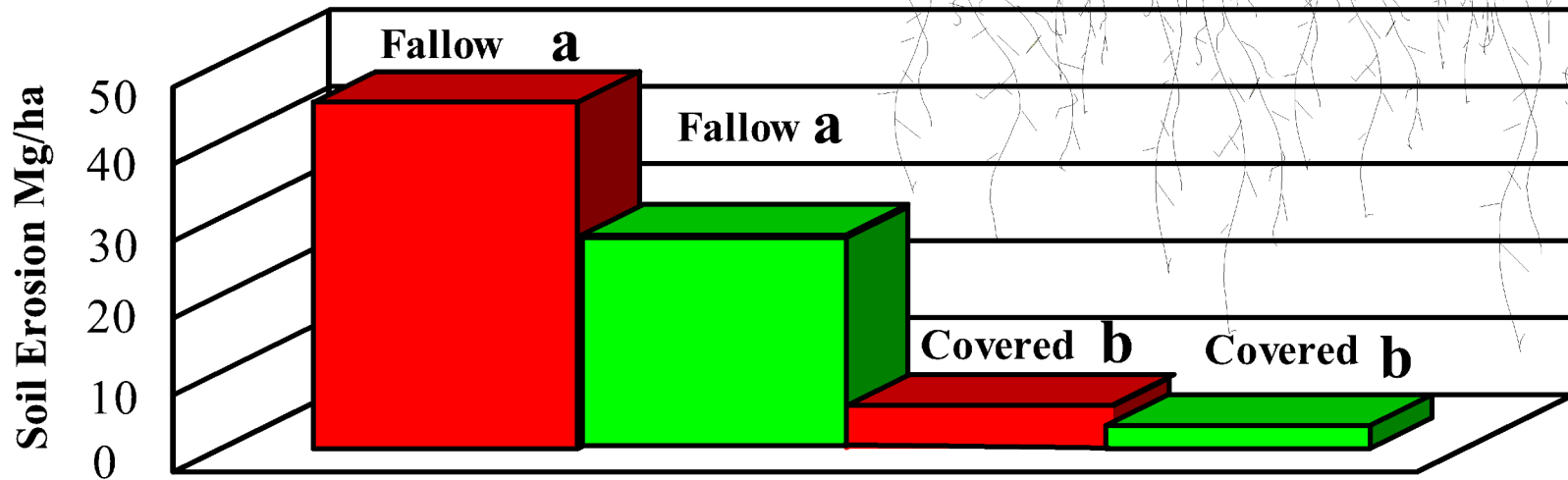
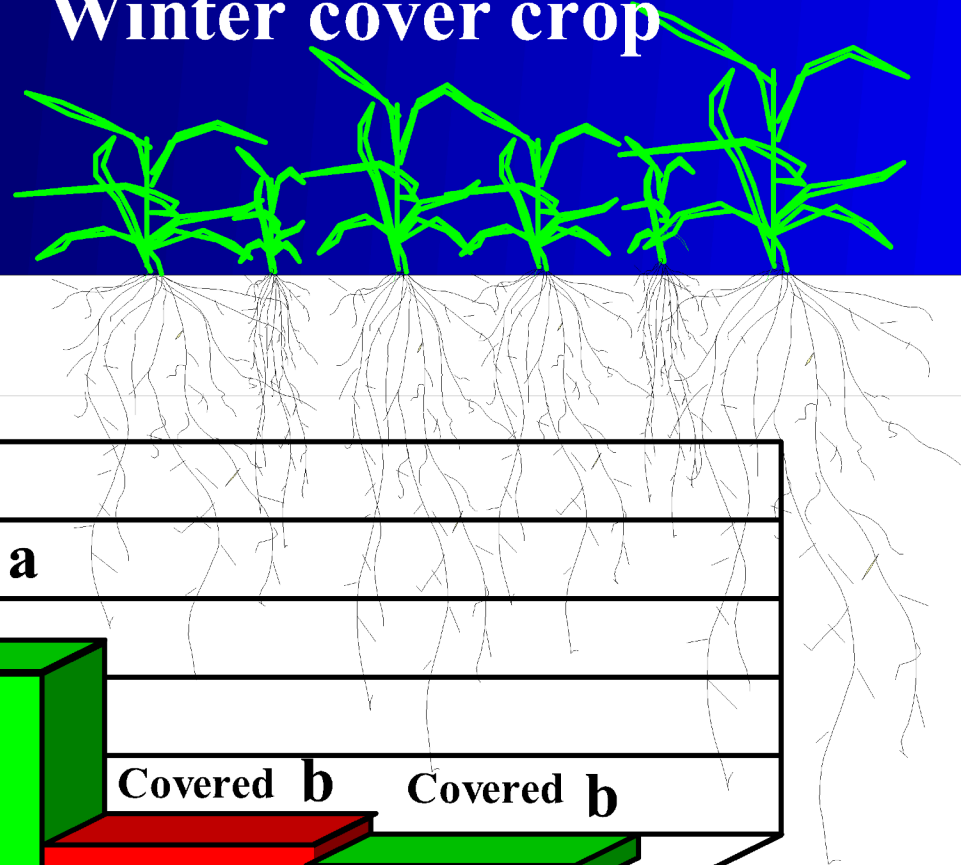
Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Cover the Surface.
 - Harvesting of plant residues should be avoided if soil function will be compromised.*

Effect of winter cover rye on potential soil erosion in fine and coarse sandy loams

Fallow

Winter cover crop



Fine Sandy loam



Coarse Sandy loam

Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Soil Function Improves with Soil Carbon.
 - *Soil C sequestration is beneficial for the environment.*



Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Off-Field Remediation Practices Are Helpful.
 - *Off-the-field conservation practices can contribute to climate change mitigation and adaptation (e.g., riparian forest buffer, wetland).*



Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Improve Landscape Diversity with Agroforestry.
 - *Agroforestry can contribute to landscape diversity, benefiting the environment.*

Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Value Water More.
 - *Water-use efficiency needs to be increased, and water quality needs to be protected.*

Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Soil and Water Conservation Practices for Climate Change Mitigation and Adaptation

- Greater Diversity Needed.

- Diverse cropping systems will be key to mitigating and adapting to climate change. Development of new varieties that can be used for tolerance of drought, temperature stress, and other effects of climate change will be needed.

Soil and Water Conservation Principles Applied to Climate Change Mitigation and Adaptation

Principles for Development of New Science and Technologies

- Research Pays Dividends Long Term.
 - *Research programs greatly contribute to soil and water conservation, making them important for climate change mitigation and adaptation.*

Nitrogen Management

Effect of N fertilizer on N₂O

global atmospheric greenhouse

IPCC

The IPCC has recommended accounting for several of the nitrogen inputs to agroecosystems, since these inputs are correlated with direct emissions of N_2O from soils.

The IPCC recommended that inputs from fertilizer-N, manure-N, crop residue-N, and N released via mineralization associated with soil organic matter losses (mineralization-N) be accounted for (Eggleston et al. 2006).



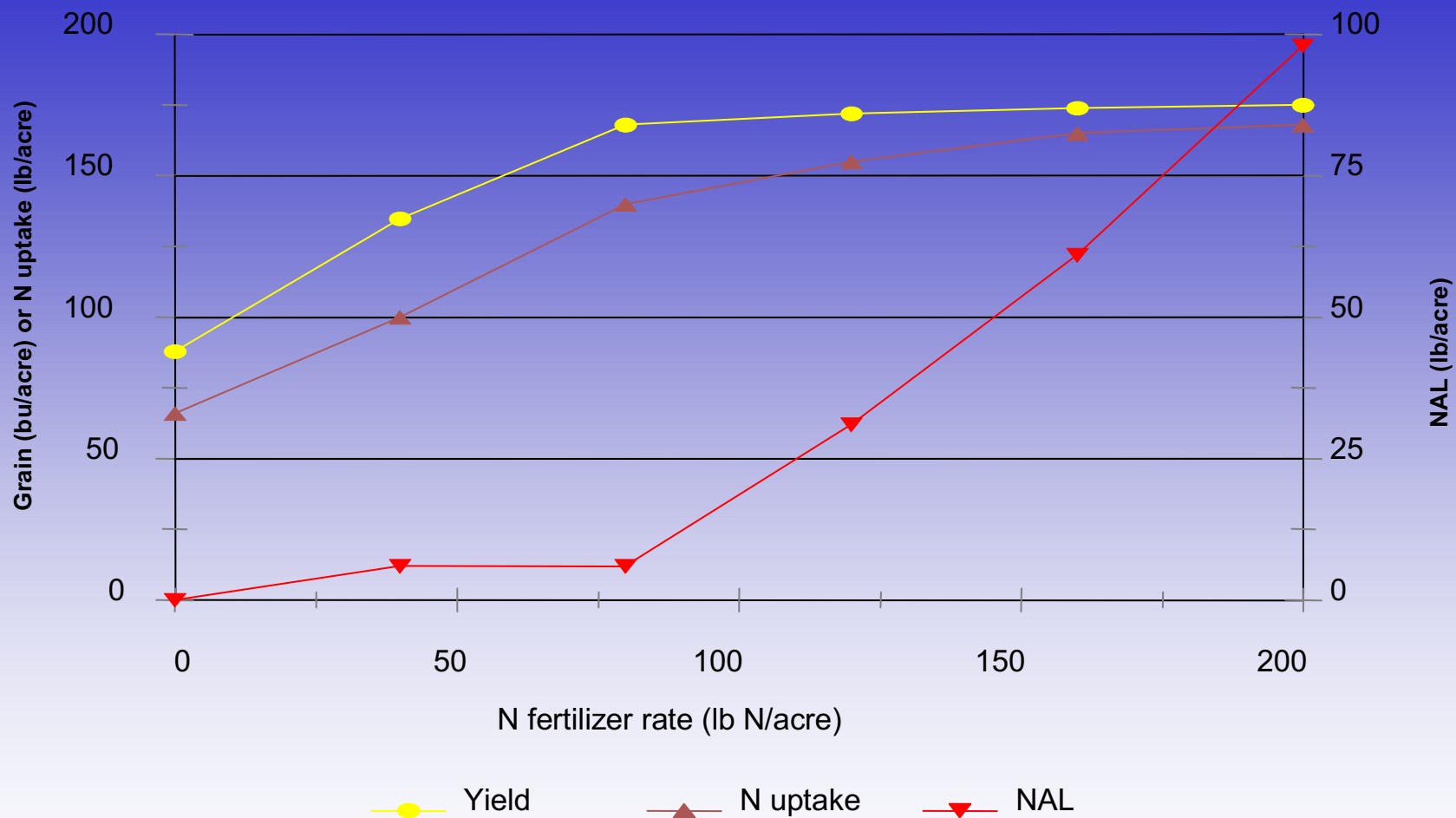


Figure 13. Effect of N fertilizer rate applications on yield and N uptake by irrigated corn (Adapted from Bock and Hergert, 1991). Potential N available to leach (NAL) assuming major pathway for losses is leaching. The NAL was estimated as $NAL = N \text{ applied} - N \text{ uptake}$.



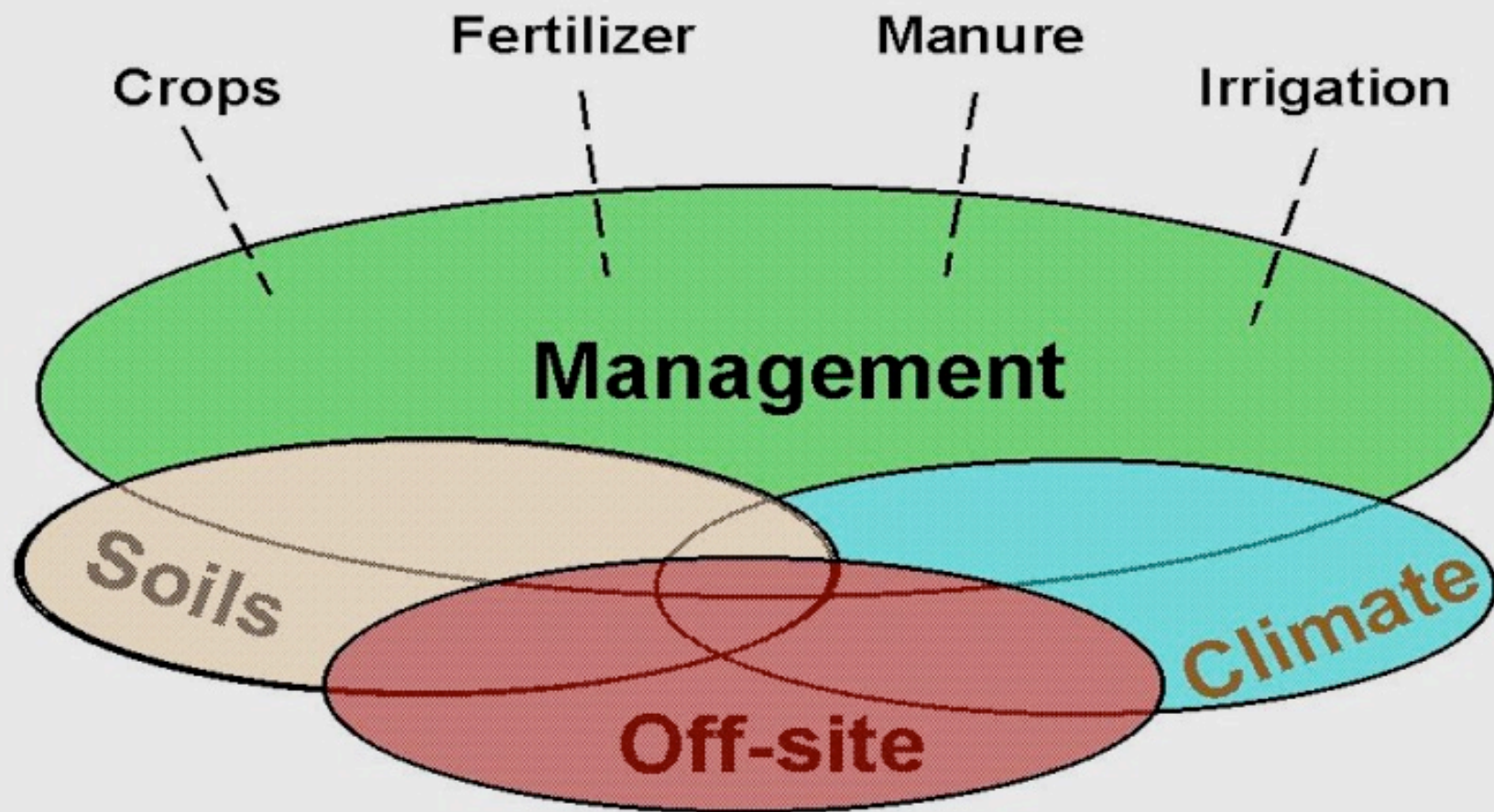
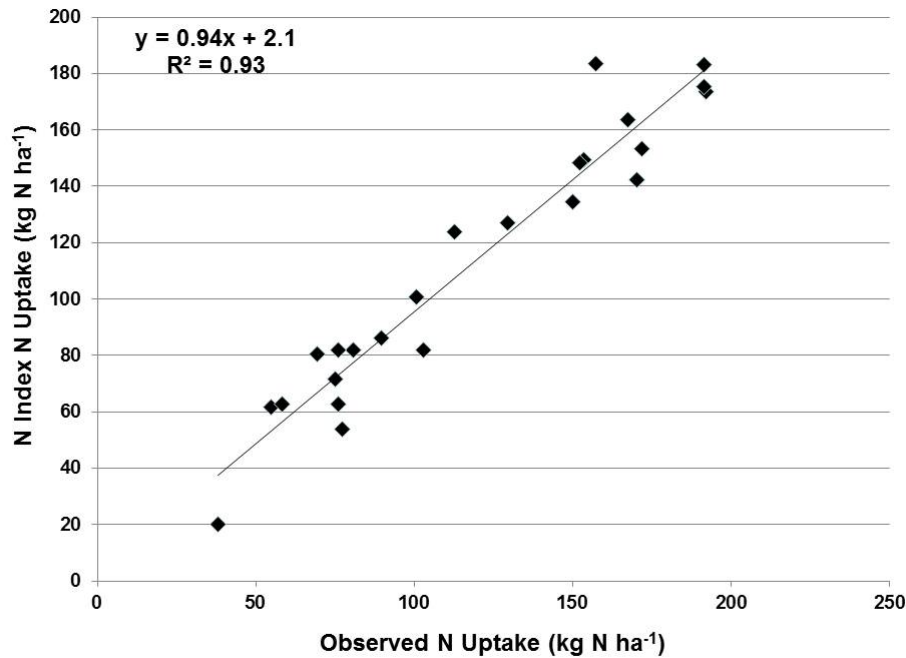
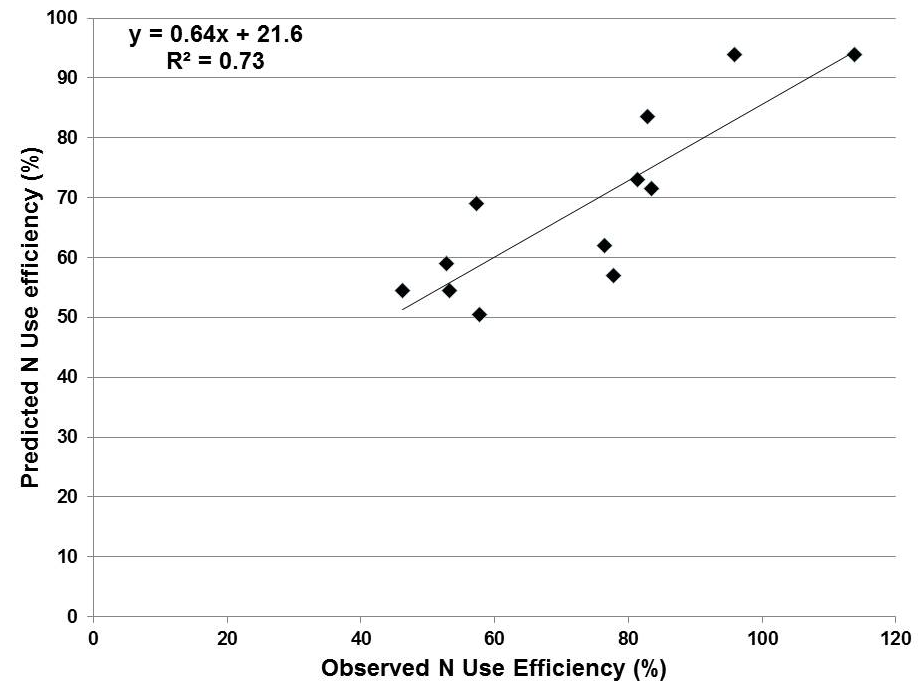


Figure 5. Essential components of $\text{NO}_3\text{-N}$ leaching index (NLI) (From Shaffer and Delgado, 2002).



The Nitrogen Index
version 4.4.2 is
currently being used
in Ecuador to assess
nitrogen management
practices.



The Nitrogen Index version 4.4.2 is currently being used in Mexico to assess nitrogen management practices.

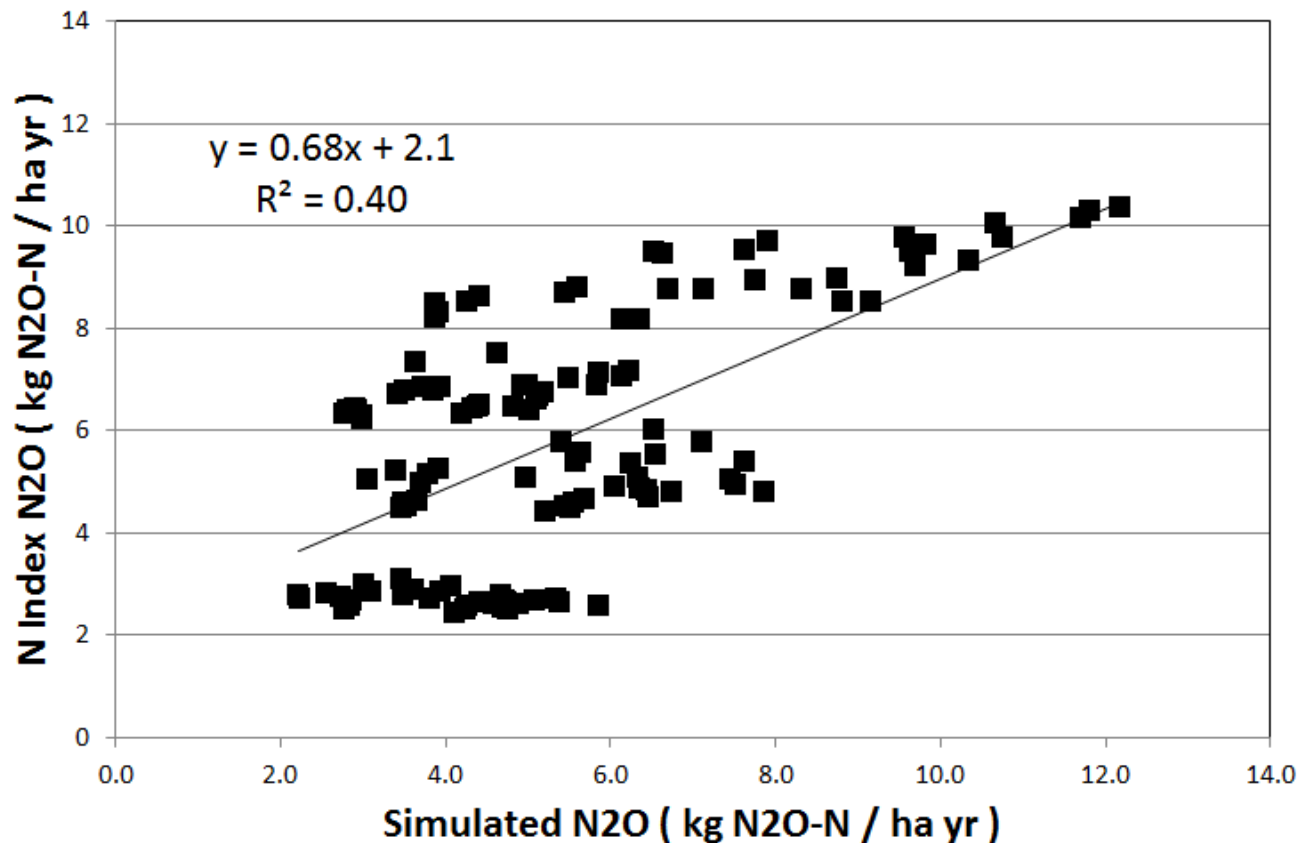


Table 1. Over 50 technicians and agricultural experts representing more than five institutions participated in a two-day training using the prototype of Nitrogen Index 4.5. Above are responses from participants on their level of knowledge before and after being trained in using the tool (on a scale of 1-5, where 1 is the lowest, and 5 is the highest).

	Average Before	Average After
Understanding of Nitrogen		
1 Describe the nitrogen cycle	3.19	4.21
2 Describe the difference between direct and indirect N2O emissions	2.44	4.26
3 Describe the relationship between nitrogen inputs and greenhouse gas emissions	2.78	4.15
Management of Nitrogen		
4 Identify and use at least four different management practices that can increase nitrogen use efficiency and reduce nitrogen losses	3.42	4.38
5 Make recommendations for fertilizer usage based on their management practices	3.36	4.26
6 Assess and estimate N2O emissions from agricultural management practices	2.44	3.85
Technology Transfer		
7 Compare and contrast two different nitrogen management tools and their advantages and disadvantages	3.03	4.12
8 Ability to train other nutrient managers, farmers, students and peers on how to manage nitrogen	2.86	4.03
9 Ability to create a plan to manage nitrogen	2.71	3.97
Average of differences		
	average before	average after
	2.92	4.14